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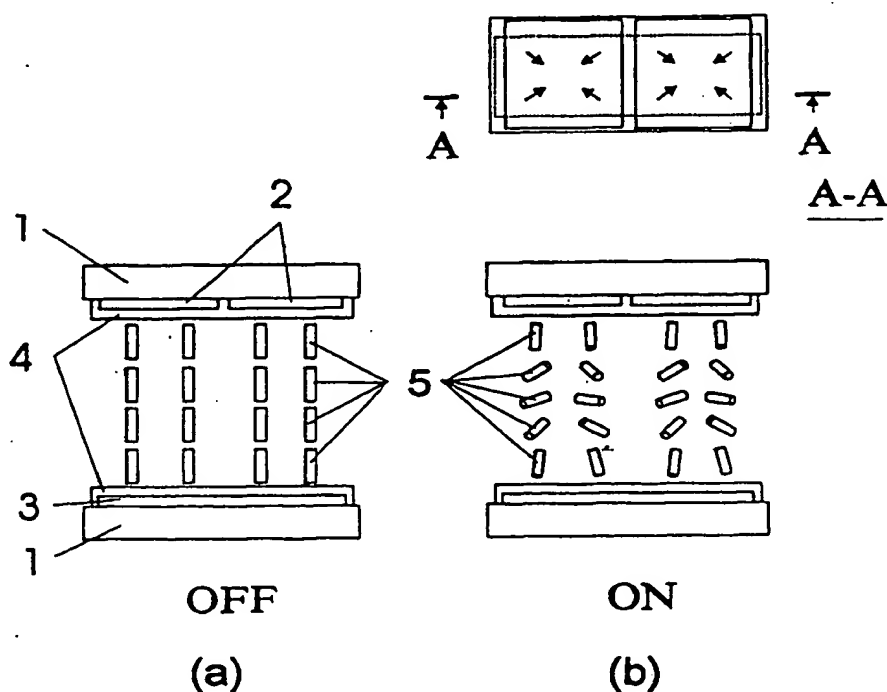
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<p>(21) International Application Number: <b>PCT/BY98/00004</b></p> <p>(22) International Filing Date: <b>21 April 1998 (21.04.98)</b></p> <p>(30) Priority Data: <b>970314 10 June 1997 (10.06.97) BY</b></p> <p>(71)(72) Applicants and Inventors: <b>KONOVALOV Victor A. [BY/BY]; Yakubova Street, 6-4-26, Minsk, 220095 (BY). MINKO, Anatoly A. [BY/BY]; Pulikhova Street, 31-1-3, Minsk, 220088 (BY). MURAVSKY, Anatoly A. [BY/BY]; Plekhanova Street, 53-88, Minsk, 220085 (BY). YAKOVENKO, Sergey E. [BY/BY]; per. Kaliningradsky, 13-95, Minsk, 220012 (BY).</b></p> <p>(74) Agent: <b>GORYACHKO, Mariam Sh.; P.O. Box 133, Minsk, 220012 (BY).</b></p>	<p>(81) Designated States: <b>AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).</b></p> <p><b>Published</b> <i>With international search report.</i> <i>With amended claims and statement.</i></p>	

(54) Title: **LIQUID CRYSTAL DISPLAY WITH WIDE VIEWING ANGLE AND METHOD FOR MAKING IT**

## (57) Abstract

The present invention relates generally to the field of electronics and may be used for making displays and, in particular, liquid crystal information displays, panels, cells; etc. The object of the invention is to simplify the method for making liquid crystal devices by reducing the number of technological operations and consequently to reduce the cost of liquid crystal display without sacrificing the quality (wide viewing angle). To achieve this the electric field applied to the liquid crystal in such display has the non-uniform component parallel to the plane of the substrates (1), which leads to the non-uniform reorientation of the aforementioned liquid crystal (5) in the space between the aforementioned electrodes (2, 3) within the pixel area and hence improves optical properties of this display in various directions of observation.



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## THE LIQUID CRYSTAL DISPLAY WITH WIDE VIEWING ANGLE AND METHOD FOR MAKING IT

5

### Field of the Invention

The present invention relates generally to the field of electronics and may be used for making displays and, in particular, liquid crystal information displays, panels, cells e.t.c.

10

### Prior Art

The methods for making liquid crystal displays are known [I.C.Khoo, S.T.Wu, Optics and nonlinear optics of liquid crystals (World Scientific, London) 1993, 390p.- 1]. Basically, they consist of depositing on two flat substrates electrical conductive and planar alignment layers and filling the space between the substrates with liquid crystal with positive dielectric anisotropy. Orientation of the liquid crystal is gradually twisted to  $90^\circ$  in the plane of the substrates. Polarization of the light passing such display is similarly twisted and in crossed polaroids it transmits light. By applying electric field to the electrodes optical axis of the liquid crystal is reoriented perpendicular to the electrodes and such device does not rotate more the light polarization. Due to this in crossed polaroids such device does not transmit light. A set of bright and dark elements makes any picture, half-tone picture as well, because the degree of light transmission gradually depends on the value of the applied voltage.

There are also known liquid crystal devices and methods for making them, as that one described in [S.T.Wu, C.S.Wu, SID Digest 27, 763 (1996) - 2]. According to it a chiral liquid crystal with negative dielectric anisotropy is placed between the substrates supplied with electrically conductive electrodes and homeotropically aligning coatings. In crossed polaroids such device does not transmit the light. Under applied electric field optical axis of the liquid crystal tends to orient perpendicular to the electric field in the whole space between the substrates. Given the chirality of the liquid crystal is such that the pitch of its spontaneous twist equals for times the liquid crystal thickness, then under the electric field the liquid crystal spontaneously twists to  $90^\circ$ . In the vicinity of the substrates orientation of the liquid crystal is

which is caused either by the anisotropy of the design, or by the residual anisotropy of the homeotropically aligning coating. With polaroids oriented parallel to the liquid crystal optical axis close to the adjacent substrate (and consequently perpendicularly to each other) one can provide such conditions, when polarization of the light follows the liquid crystal orientation. With electric field applied, such device transmits light, the amount of which may be gradually reduced by decreasing the applied voltage.

The drawback of this device, as well as of that one described in [1], is strong dependence of its transmission on the incidence angle of light. As a consequence, at some observation angles strong decrease of the contrast and even its inversion are observed.

According to the technical reference, which is the closest to the proposed one from the point of view of its technical content, to reduce this undesirable phenomenon the known method [1] is modified so, that the area of each pixel consists of domains with various possible orientation of the liquid crystal in the plane of the substrates [M.Schadt, Proc.SID'97, 24.1 (1997).- 3]. This is achieved by depositing photocured polymer coating with the subsequent irradiation of different domains of a pixel with ultraviolet light of various polarization (applying multiple photolithography with precise alignment). Liquid crystal alignment at the surface of such coating is determined by the polarization of the polymerizing radiation and therefore is different in different domains of a pixel. In such a case, light transmission of each pixel is the sum of the transmissions of domains with different orientation of the liquid crystal and therefore does not depend on the azimuthal viewing angle. This also eliminates inversion of the intermediate transmission levels. Complexity and high cost (due to multiple photolithography) are the drawbacks of this Technical reference.

Another device is commonly used. [N.Yamagishi, H.Watanabe, K.Yokoyama, 'Japan Display 89', 316 (1989) - 4], according to which the viewing angle of liquid crystal devices is improved by using special retardation films between the liquid crystal layer and polaroids. Unfortunately, this increases the cost of such devices.

### Summary of the Invention

The object of invention is to simplify the method for making liquid crystal devices by reducing the number of technological operations and consequently to reduce the cost of liquid crystal display without sacrificing the quality (wide viewing angle).

To achieve this, the electric field applied to the liquid crystal in such display has the non-uniform component parallel to the plane of the substrates, which leads to the non-uniform reorientation of the aforementioned liquid crystal in the space between the aforementioned electrodes within the pixel area and hence improves optical properties of this display in various directions of observation.

According to the method electrically conducting and homeotropically aligning layers are deposited on the surfaces of two flat substrates, faced to each other and fill the space between these substrates with the liquid crystal possessing negative dielectric anisotropy. Without electric field the liquid crystal molecules are orthogonal to the substrates and this device does not transmit light in crossed polaroids. Under electric field liquid crystal reorients perpendicular to the electric field not uniformly across the pixel area, but according to the direction of the in-plane component of the electric field. In this way the domains with different (including opposite) orientation of liquid crystal are formed. At various viewing angles different domains have different transmission levels and transmittance of the whole pixel equals to some averaged value. Due to this the phenomenon of inversion of levels with intermediate transmission is reduced for all observation angles, as this takes place in the known device [3].

One can also use non-chiral as well as chiral liquid crystal. In the first case, light transmittance of the liquid crystal between crossed polaroids planarly aligned by the electric field is caused only by birefringence of the liquid crystal. To maximize transmittance under electric field one should align polaroids at  $45^\circ$  to the optical axis of the liquid crystal and the doubled product of the liquid crystal thickness by its birefringence should be equal to the odd number of the light wavelengths. There are four possible variants of such orientation of the liquid crystal and the case, when all four kinds of these domains occupy similar area, meets the requirements of this invention best of all. Due to decrease of the light transmittance with the deviations of the liquid crystal from optimal orientation, the maximal transmittance value can be achieved when under electric field the liquid crystal forms domains with uniform orientation of the liquid crystal within the domain area, the aforementioned orientation having  $45^\circ$  angle with the polaroids direction.

Transmittance of the twisted nematic liquid crystal structure between crossed polaroids depends on the orientation of the liquid crystal axis in their vicinity relative to the polaroids axes. In the case they coincide and the product of the liquid crystal thickness by its birefringence exceeds the light wavelength, polarization of the transmitted light

follows the liquid crystal twist. This ensures maximal transmittance of the known device fabricated according to the known method [3] under electric field provided this electric field exceeds the threshold value for the particular liquid crystal. In the proposed device fabricated according to the proposed method the liquid crystal can have various orientation of its optical axis under electric field and to achieve maximal transmittance one should have the product of the liquid crystal thickness by its birefringence equal to the integer number of the light wavelengths. In this case polarization of the light passing the liquid crystal is also twisted to 90° and practically 100% of light are transmitted by the second polaroid.

The aforementioned requirements to the liquid crystal thickness are valid when both substrates and both electrodes are transparent and the device according the invention is used to display image with the transmitted light. In the case the device according the invention is used in reflection mode, one of the aforementioned substrates and the electrode deposited on it are made non-transparent (reflective) and for displaying image only one polaroid is used. In this case the preferred orientation (twisted, or not; configuration of domains) and thickness of the liquid crystal in various areas may be calculated with the methods [D.W.Berberman, Appl.Phys.Letters, 35, 12 (1974) - 5] known for homogeneously aligned nematic structures. To increase the contrast one may combine the proposed method with the known one [4] in which retardation films are used. According to the proposed method one may introduce dichroic dyes in the liquid crystal filling the gap between the substrates and then such device may display images without polaroids but due to the light absorption by the dye molecules. The aforementioned dye may have dichroic ratio larger than one or smaller and the aforementioned liquid crystal may be both chiral or non-chiral.

There are various methods to create in-plane with the electrodes component of the electric field, when it is applied to the liquid crystal. For example, this can be achieved by special patterning of the electrodes surrounding the liquid crystal, or by displacing dielectric particles by depositing special dielectric films being relieved as on the liquid crystal side so on the substrate side, said particles divide the pixel into parts with different orientation of the electric field. Even the pixel edges themselves cause the non-uniformity of the electric field in the vicinity of the pixel borders and therefore they also may be used for this purpose. Essential is to create such conditions that electric field



applied to the liquid crystal has parallel to the substrates components, these components have different direction i.e. different azimuth angle in different pixel areas.

#### Brief Description of Drawings

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Fig.1 displays the cross-section of the liquid crystal display according to [2] in the state without (a) and with (b) the electric field applied to the liquid crystal. The display consists of the glass substrates 1 with the column 2 and row 3 electrodes deposited on them and homeotropically aligning coating 4. Liquid crystal 5, the molecules of which are shown as cylinders, is placed between the glass substrates 1.

10

In Fig.2 the top view and the cross-section of the liquid crystal device according the invention is shown in the state without (a) and with (b) the electric field applied to the liquid crystal. Liquid crystal 5, the molecules of which are shown as cylinders, is placed between the glass substrates 1 with the column 2 and row 3 electrodes deposited on them and homeotropically aligning coating 4. Different columns of cylinders correspond to the domains with different orientation of the liquid crystal (rotated to about 150 degrees in the plane of the substrates 1). The arrows show orientation of the liquid crystal in the central plane of the device.

15

In Fig.3 the top view and the cross-section of the electrodes pattern are shown schematically for the segment-type (a) and the matrix-type (b) liquid crystal devices. The arrows show the force lines of the electric field. The component of the electric field parallel to the substrates is shown at the edges of the electrodes.

20

Fig.4 schematically shows the top view and the cross-section of the electrodes. The arrows show the force lines of the electric field. The component of the electric field parallel to the substrates is shown arising at the slits in the electrodes.

25

Fig.5 schematically shows the top view and the cross-section of the electrodes. The arrows show the force lines of the electric field. The component of the electric field parallel to the substrates is shown arising when different polarity is applied to the electrodes comprising the same pixel.

30

Fig.6 schematically shows the top view and the cross-section of the electrodes. The arrows show the force lines of the electric field. The component of the electric field parallel to the substrates is shown arising around the additional dielectric particle with the dielectric permittivity different from that of the liquid crystal.

In Fig.7 the light transmittance of the device made according to the known method [2] is displayed as a function of azimuth angle for the polar viewing angle equal 30 (a) and 50 (b) degrees. Different curves correspond to different levels of the applied electric field (its amplitude in Volts is shown in the brackets).

5 In Fig.8 the light transmittance of the device according the invention is displayed as a function of azimuth angle for the polar viewing angle equal 30 (a) and 50 (b) degrees. Different curves correspond to different levels of the applied electric field (its amplitude in Volts is shown in the brackets).

## 10 Detailed Description of the Invention

According to the proposed method we made liquid crystal display. For this, at the glass substrates 1 0.5 - 2 mm thick and with linear dimensions from 1 cm to several decimeters we deposited by vacuum sputtering column 2 and row 3 transparent electrodes 70-150  
15 nm thick, made of indium-tin oxide with the surface resistivity 20-2000 Ohm/□. The electrodes were patterned photolithographically. At the same surfaces homeotropically aligning coating 4, such as lecithin, with the thickness 20-80 nm was spinned and baked. The substrates were overlaid with the aligning layers faced to each other, sealed with the glue based on epoxy resin and the gap was filled with the liquid crystal with negative  
20 dielectric anisotropy. The conditions for appearing the component of the electric field parallel to the substrates, when this electric field is applied through the electrodes 2 and 3 to the liquid crystal, were created by one of the methods described below.

Conditions for appearing the parallel to the substrates component of the electric field can be created in various ways. The opposite electrodes in the segment-type liquid crystal  
25 device can be made of different dimensions, as it is shown, for example, in Fig.3. Then, at the edges of the segment, electric field is orthogonal to the substrates not in the entire space between the electrodes (Fig.3a). In the matrix-type liquid crystal device (Fig.3b) electric field inevitably has the component parallel to the substrates and in the case the width of the electrodes 2 and/or 3 is comparable (not more than 3-5 time exceeds) the  
30 thickness of the liquid crystal layer, this component is sufficient for dividing the pixel into even parts with different orientation of the liquid crystal. In the cases, when the pixels should be of larger dimensions (should exceed the liquid crystal thickness many times) big number of domains with the electric field substantially non-orthogonal to the substrates can be obtained by dividing the electrodes into the parts, as it is shown in

Fig.4. Even stronger horizontal component of the electric field can be obtained if even and odd parts of the electrode are connected to the electric field sources of the opposite polarity, as it is shown in Fig.5. Alternatively, big number of domains with the electric field substantially non-orthogonal to the substrates can be obtained by displacing  
5 between the electrodes at the opposite substrates a big number of particles with the dielectric permittivity essentially different from that of the liquid crystal (Fig.6). It can be realized by depositing special dielectric films being released as on liquid crystal side so on the substrate side.

- 10 The device according the invention operates as follows. In the state without the electric field the aligning coating 4 aligns the liquid crystal molecules perpendicular to the substrates 1. In this state the liquid crystal does not influence the polarization of the light passing it and in the crossed polaroids transmittance of the liquid crystal device equals zero. When electric field exceeding the threshold for the particular liquid crystal is  
15 applied to the transparent electrodes 2 and 3, the liquid crystal molecules tend to reorient perpendicular to the field. The liquid crystal begins to change polarization of the light passing it and transmittance of the liquid crystal device becomes different from zero. Existence of the component of the electric field which is parallel to the substrates and non-uniformly oriented within the pixel area makes the molecules to decline from the  
20 normal to the substrates 1 in different directions (Fig.2) in difference to what happens in the known device (Fig.1). At various viewing angles different domains have different transmittance and the transmittance of the whole pixel equals to some averaged value. Due to this, opposite to the transmittance of the device made without creating conditions for non-uniform reorientation of the liquid crystal under electric field (Fig.7), inversion  
25 of the transmittance levels of the liquid crystal display is reduced for all viewing angles (Fig.8).

Tests of the proposed method and the display made by it have evidenced smaller number of operations required to make a display in comparison to the nearest Prior Art method  
30 (multiple illuminations by the ultraviolet light with precise alignment of different photomasks are not required). Simultaneously, the display according the invention possesses similarly even angular dependence of the transmittance, high contrast and the absence of the inversion of the transmittance levels at oblique observation angles.

## CLAIMS

1. Liquid crystal display with wide viewing angle comprising nematic liquid crystal with negative dielectric anisotropy placed between flat parallel substrates supplied with conductive electrodes and homeotropic aligning layers,  
5 characterized in that orientation of the said liquid crystal is made non-uniform within the pixel area by means of the parallel to the said substrates components of the electric field applied to the said electrodes, while the components themselves have various directions.
- 10 2. Display according to claim 1, characterized in that the doubled product of the liquid crystal thickness by its birefringence is made equal to the odd number of the light wavelengths.
3. Display according to claim 1, characterized in that the said liquid crystal contains chiral dopant in such amount, that equilibrium pitch of the said liquid crystal equals  
15 four times the thickness of the liquid crystal layer.
4. Display according to claim 3, characterized in that the said thickness of the liquid crystal layer is made so that its doubled product with the birefringence of the said liquid crystal equals odd number of the wavelengths of light.
5. Display according to claim 1, characterized in that one of the said electrodes is made  
20 reflective.
6. Display according to claim 1, characterized in that the said electrodes are made of not similar dimensions.
7. Display according to claim 1, characterized in that at least one of the said electrodes is made sectional.
8. Display according to claim 1, characterized in that odd and even sections of the said  
25 electrodes are connected to the electric field sources of the opposite polarity.
9. Display according to claim 1, characterized in that in the space occupied by the said liquid crystal dielectric particles are displaced with dielectric constant essentially different from dielectric permittivity of the said liquid crystal.
- 30 10. Method for making liquid crystal display with wide viewing angle comprising the deposition on conductive electrodes and homeotropic aligning layers of the faced to each other surfaces of the flat parallel substrates and filling the space between them with nematic liquid crystal possessing negative dielectric anisotropy,

characterized in that

when electric field is applied to the said electrodes the components of the electric field parallel to the said substrates with various directions are created and due to this orientation of the said liquid crystal in the space between the said electrodes is made non-uniform.

11. Method according to claim 10, characterized in that the doubled product of the liquid crystal thickness by its birefringence is chosen to be equal to the odd number of the light wavelengths.

12. Method according to claim 10, characterized in that chiral dopant is added to the said liquid crystal in such amount, that equilibrium pitch of the said liquid crystal is made equal four times the thickness of the liquid crystal layer.

13. Method according to claim 12, characterized in that the doubled product of the birefringence of the said liquid crystal by its thickness is chosen to be equal odd number of the wavelengths of light.

14. Method according to claim 10, characterized in that one of the said electrodes is made reflective.

15. Method according to claim 10, characterized in that the said parallel to the substrates plane component of the electric field is created due to non-similarity of the dimensions of the said electrodes.

16. Method according to claim 10, characterized in that the said parallel to the substrates plane component of the electric field is created by making at least one of the said electrodes sectional.

17. Method according to claim 10, characterized in that the said parallel to the substrates plane component of the electric field is created by connecting odd and even sections of the said electrodes to the electric field sources of the opposite polarity.

18. Method according to claim 10, characterized in that the said parallel to the substrates plane component of the electric field is created by displacing in the space occupied by the said liquid crystal dielectric particles with dielectric constant essentially different from dielectric permittivity of the liquid crystal.

THE LIQUID CRYSTAL DISPLAY WITH WIDE VIEWING ANGLE AND  
METHOD FOR MAKING IT

5 The present invention relates generally to the field of electronics and may be used for making displays and, in particular, liquid crystal information displays, panels, cells e.t.c.

The object of invention is to simplify the method for making liquid crystal devices by reducing the number of technological operations and consequently to reduce the cost  
10 of liquid crystal display without sacrificing the quality (wide viewing angle).

To achieve this the electric field applied to the liquid crystal in such display has the non-uniform component parallel to the plane of the substrates, which leads to the non-uniform reorientation of the aforementioned liquid crystal in the space between the  
15 aforementioned electrodes within the pixel area and hence improves optical properties of this display in various directions of observation.

## AMENDED CLAIMS

[received by the International Bureau on 12 November 1998 (12.11.98);  
original claims 1-18 replaced by new claims 1-16 (3 pages)]

- 5           1. Liquid crystal display with wide viewing angle comprising nematic liquid crystal with negative dielectric anisotropy placed between flat parallel substrates supplied with conductive electrodes and homeotropic aligning layers, orientation of the said liquid crystal is made non-uniform within the pixel area by means of the parallel to the said substrates components of the electric field applied to the said electrodes, while  
10 the components themselves have various directions characterized in that in the space occupied by the said liquid crystal dielectric particles are displaced with dielectric constant essentially different from dielectric permittivity of the said liquid crystal.
- 15           2. Display according to claim 1, characterized in that the said dielectric particles are made by depositing relieved dielectric films over the aforementioned electrodes.
3. Display according to claim 1, characterized in that the doubled product of the liquid crystal thickness by its birefringence is made equal to the odd number of the  
20 light wavelengths.
4. Display according to claim 1, characterized in that the said liquid crystal contains chiral dopant with such concentration that equilibrium pitch of the said liquid crystal equals four times the liquid crystal thickness and the product of the later by the liquid crystal birefringence is made equal to the integer number of the light  
25 wavelengths.
5. Display according to claim 1, characterized in that one of the said electrodes is made reflective.
6. Liquid crystal display with wide viewing angle comprising nematic liquid crystal with negative dielectric anisotropy placed between flat parallel substrates  
30 supplied with conductive electrodes and homeotropic aligning layers, orientation of the said liquid crystal is made non-uniform within the pixel area by means of the parallel to the said substrates components of the electric field applied to the said electrodes, while the components themselves have various directions

characterized in that

odd and even sections of the at least one of the said electrodes been made sectional  
5 are connected to the electric field sources of the opposite polarity.

7. Display according to claim 6, characterized in that the doubled product of the liquid crystal thickness by its birefringence is made equal to the odd number of the light wavelengths.

8. Display according to claim 6, characterized in that the said liquid crystal  
10 contains chiral dopant with such concentration that equilibrium pitch of the said liquid crystal equals four times the liquid crystal thickness and the product of the later by the liquid crystal birefringence is made equal to the integer number of the light wavelengths.

9. Display according to claim 6, characterized in that one of the said electrodes  
15 is made reflective.

10. Method for making liquid crystal display with wide viewing angle comprising the deposition on conductive electrodes and homeotropic aligning layers of the faced to each other surfaces of the flat parallel substrates and filling the space between them with nematic liquid crystal possessing negative dielectric anisotropy,  
20 making the orientation of the said liquid crystal in the space between the said electrodes non-uniform when applying the electric field to the said electrodes with the components of the electric field parallel to the said substrates with various directions characterized in that the said parallel to the substrates plane component of the electric field is created by  
25 displacing in the space occupied by the said liquid crystal dielectric particles with dielectric constant essentially different from dielectric permittivity of the liquid crystal.

11. Method according to claim 10, characterized in that the said dielectric particles are made by depositing relieved dielectric films over the aforementioned electrodes.

30 12. Method according to claim 10, characterized in that the doubled product of the liquid crystal thickness by its birefringence is chosen to be equal to the odd number of the light wavelengths.

13. Method according to claim 10, characterized in that chiral dopant is added to the said liquid crystal with such concentration that equilibrium pitch of the said



liquid crystal equals four times the liquid crystal thickness and the product of the later  
by the liquid crystal birefringence is made equal to the integer number of the light  
5 wavelengths.

14. Method for making liquid crystal display with wide viewing angle  
comprising the deposition of conductive electrodes and homeotropic aligning layers on  
the faced to each other surfaces of the flat parallel substrates and filling the space  
between them with nematic liquid crystal possessing negative dielectric anisotropy,  
10 making the orientation of the said liquid crystal in the space between the said  
electrodes non-uniform when applying the electric field to the said electrodes with the  
components of the electric field parallel to the said substrates with various directions  
characterized in that  
the said parallel to the substrates plane component of the electric field is created by  
15 connecting odd and even sections of the said electrodes been made sectional to the  
electric field sources of the opposite polarity.

15. Method according to claim 14, characterized in that the doubled product of  
the liquid crystal thickness by its birefringence is chosen to be equal to the odd number  
of the light wavelengths.

20 16. Method according to claim 14, characterized in that chiral dopant is added  
to the said liquid crystal with such concentration that equilibrium pitch of the said  
liquid crystal equals four times the liquid crystal thickness and the product of the later  
by the liquid crystal birefringence is made equal to the integer number of the light  
wavelengths.

**STATEMENT UNDER ARTICLE 19(1)**

The amendments have been made since the prior art cited in the International Search Report contains the features present in the original Claims.

The original claims 1, 6, 7, 15, 16 have been canceled because the features of these claims fully coincide with the features known from the above prior art.

The original claims 2, 3, 4, 5, 8, 9, 11, 12, 13, 14, 17, 18 have been amended and substituted with the new claims 1-16.

In the new independent claims 1, 6, 10 and 14 the features of the original claims 9, 8, 18 and 17 accordingly have been used.

In the new claims 3 and 7 the features of the original claim 2 have been used, in the new claims 5 and 9 the features of the original claim 5 have been used, in the new claims 12 and 15 the features of the original claim 11 have been used.

In the new claims 3 and 8 the features of the original claims 3 and 4 and of the disclosure have been combined.

In the new claims 13 and 16 the features of the original claims 12 and 13 and of the disclosure have been combined.

The new claims 2 and 11 have been created on the basis of disclosure.

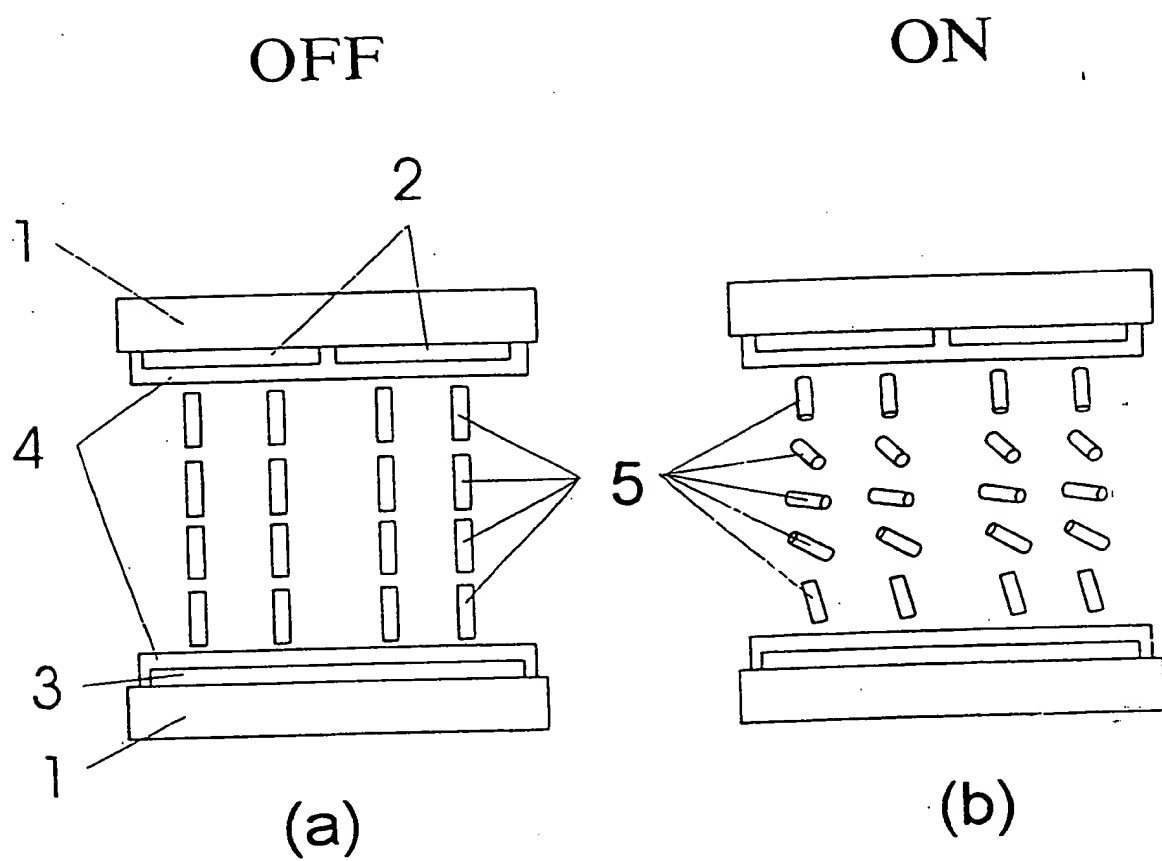


Fig.1

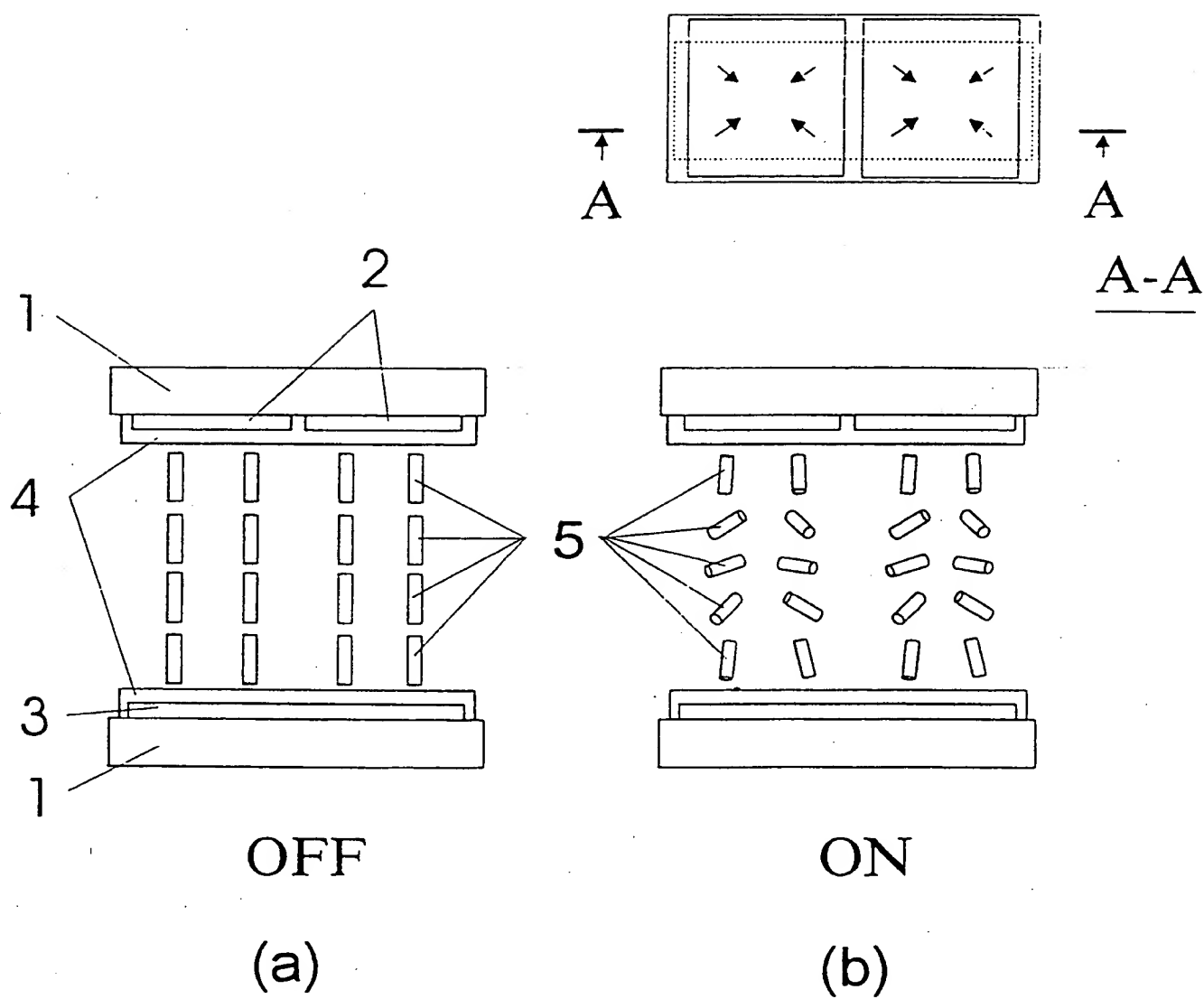


Fig.2

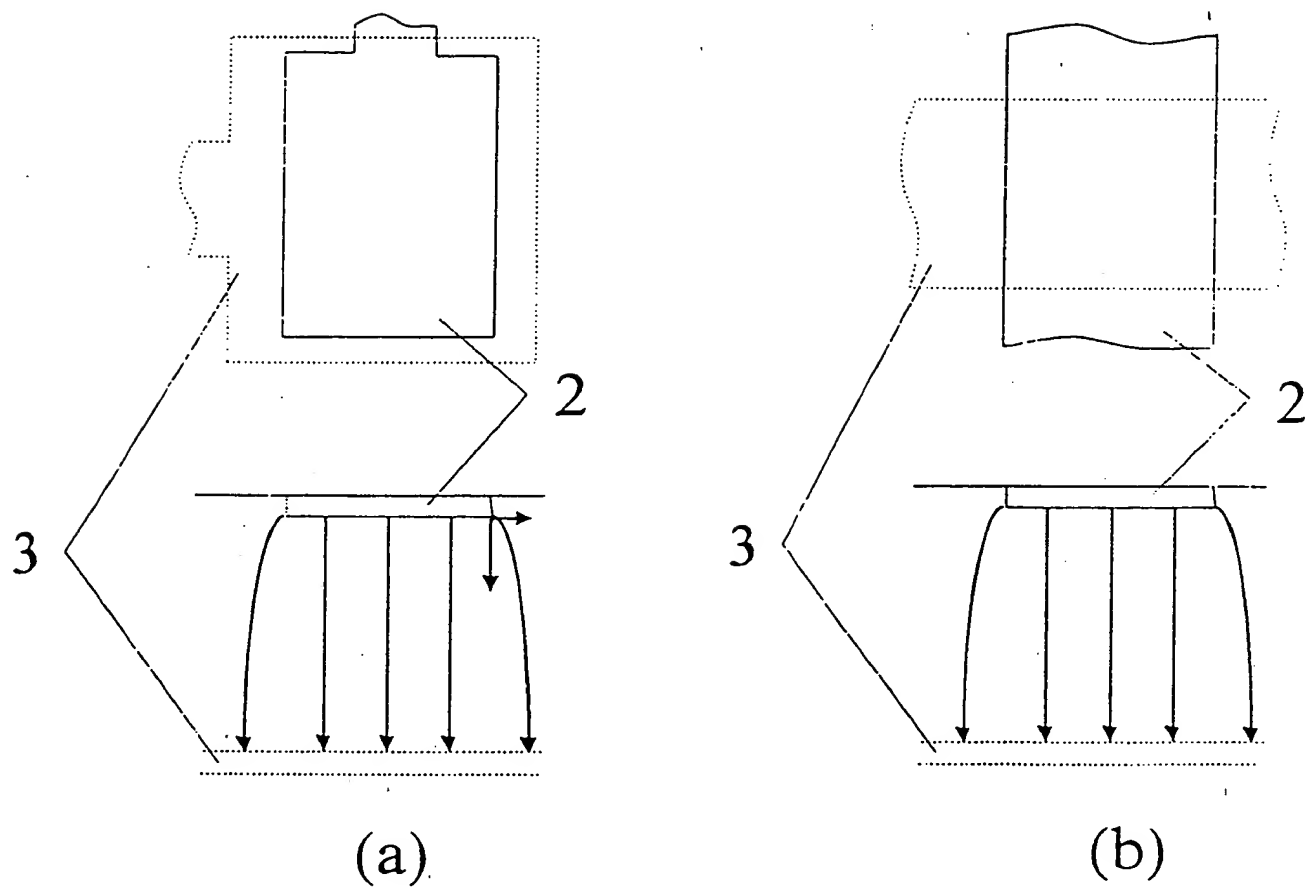


Fig.3

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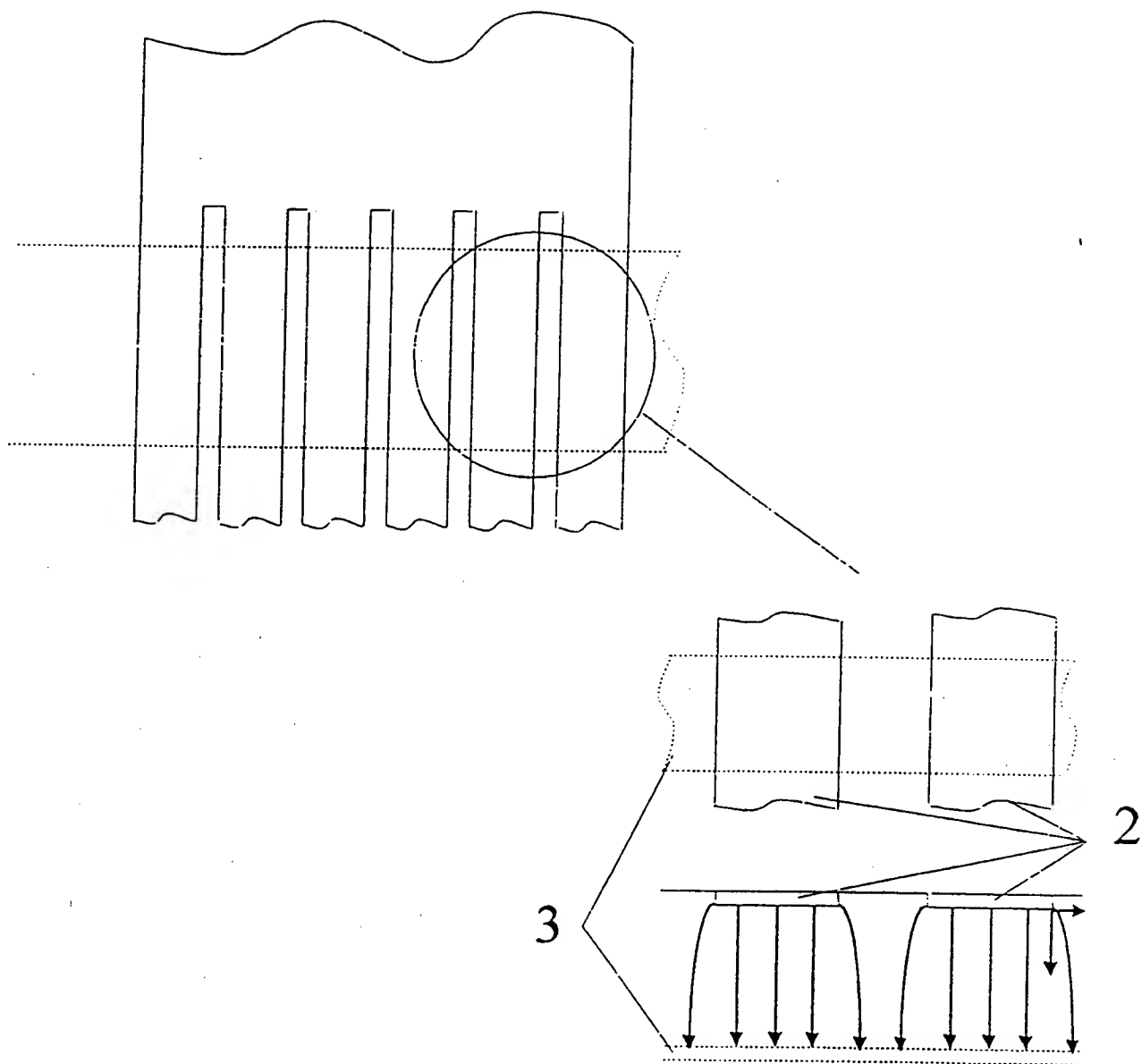


Fig.4

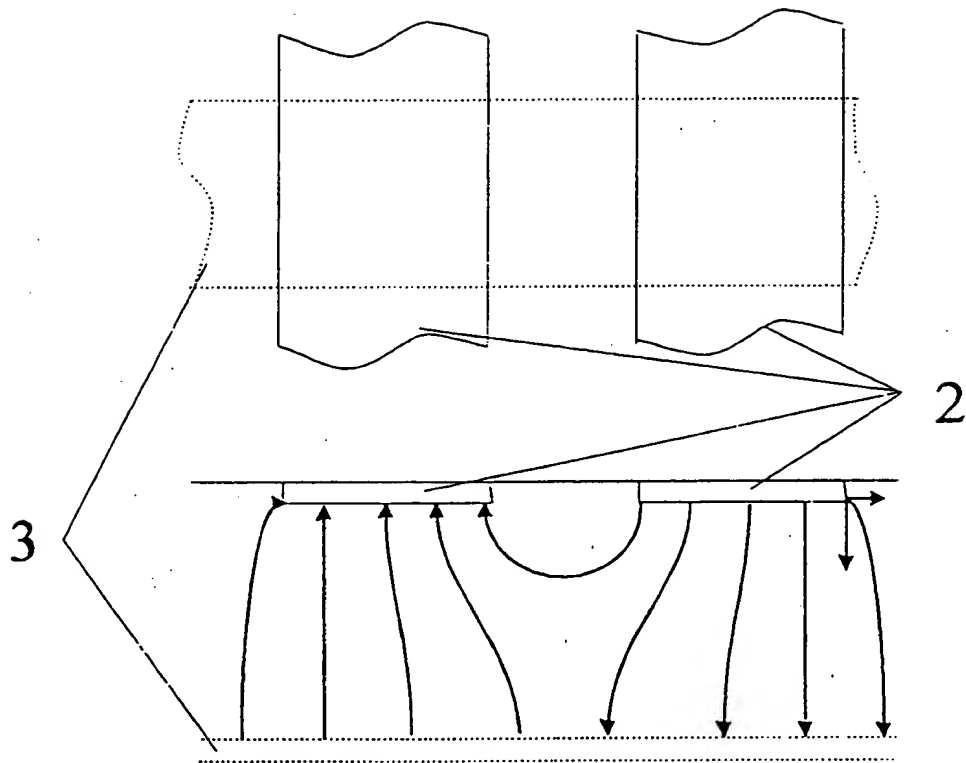


Fig.5

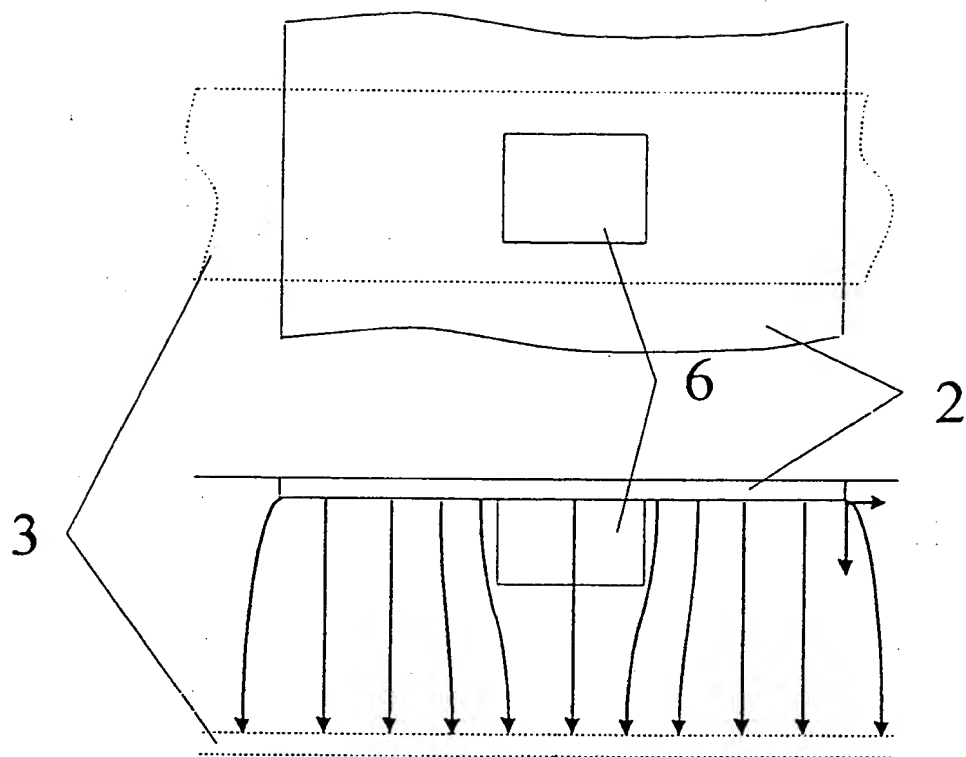
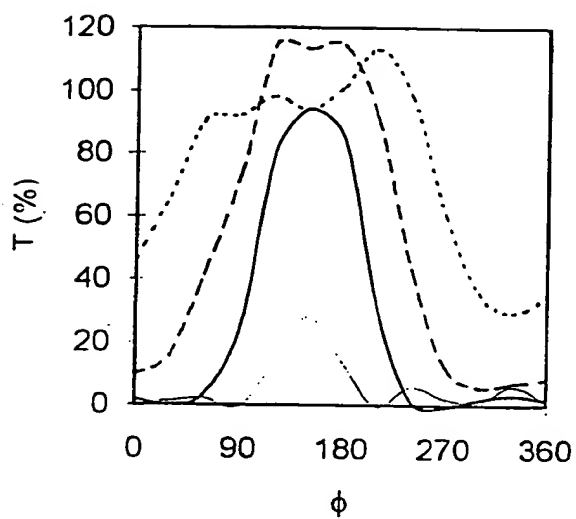


Fig.6

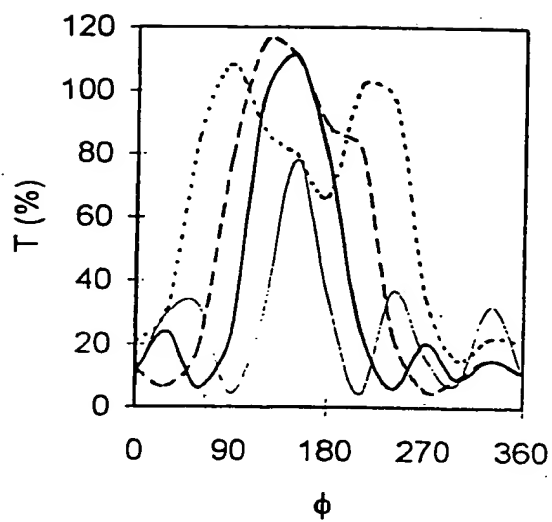


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.....  $v_0$                       —  $v_{10} (4.13)$   
---  $v_{50} (4.80)$             - · - ·  $v_{90} (5.90)$

(a)

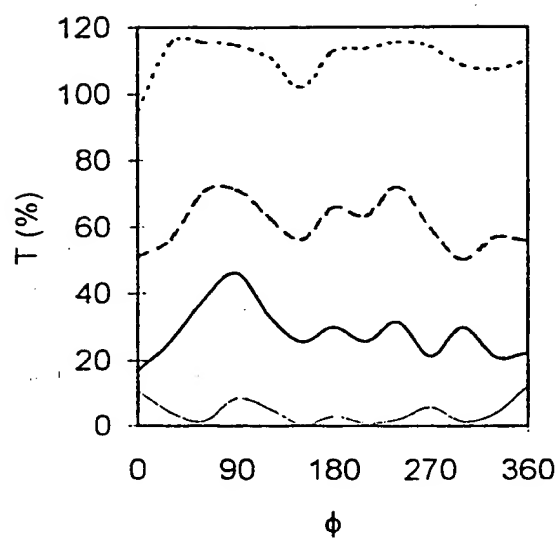


.....  $v_0$                       —  $v_{10} (4.10)$   
---  $v_{50} (4.68)$             - · - ·  $v_{90} (5.69)$

(b)

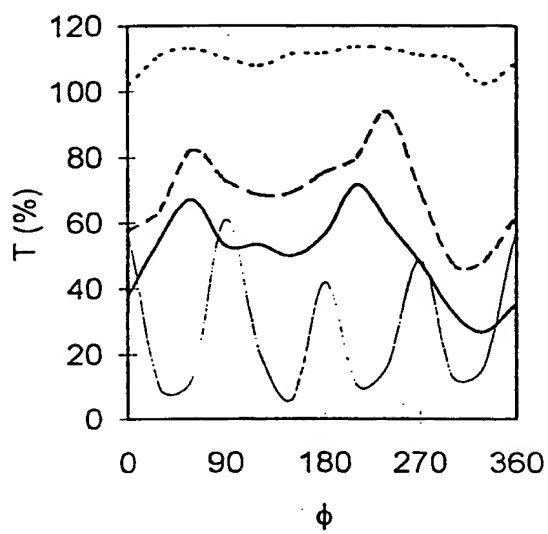
Fig.7

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-----  $v0$                       —  $v10$  (4.50)  
- - -  $v50$  (4.60)              .....  $v90$  (5.90)

(a)



-----  $v0$                       —  $v10$  (4.50)  
- - -  $v50$  (4.60)              .....  $v90$  (5.90)

(b)

Fig.8

# INTERNATIONAL SEARCH REPORT

International Application No.

PCT/BY 98/00004

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 G02F1/1337 G02F1/1343

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 G02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 96 10774 A (ROCKWELL INTERNATIONAL CORP) 11 April 1996 see page 12, paragraph 2 - paragraph 4; figures 6,7	1,3,7, 10,12,16
X	YAMAMOTO T ET AL: "35.7: FULL-CONE WIDE-VIEWING-ANGLE MULTICOLOR CSH-LCD" SID INTERNATIONAL SYMPOSIUM DIGEST OF TECHNICAL PAPERS, ANAHEIM, MAY 6 - 10, 1991, no. VOL. 22, 6 May 1991, pages 762-765, XP000503124 SOCIETY FOR INFORMATION DISPLAY see page 763, left-hand column, paragraph 2 - paragraph 4; figures 4A,4B	1,6,10, 15
	--- -/--	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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- \*O\* document referring to an oral disclosure, use, exhibition or other means
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- \*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- \*8\* document member of the same patent family

Date of the actual completion of the international search

15 September 1998

Date of mailing of the international search report

22/09/1998

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# INTERNATIONAL SEARCH REPORT

International Application No.

PCT/BY 98/00004

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>PATENT ABSTRACTS OF JAPAN  vol. 095, no. 005, 30 June 1995  &amp; JP 07 043698 A (SHARP CORP),  14 February 1995  see abstract</p> <p>-----</p>	1,9

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/BY 98/00004

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9610774 A	11-04-1996	JP 10506479 T	23-06-1998

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